

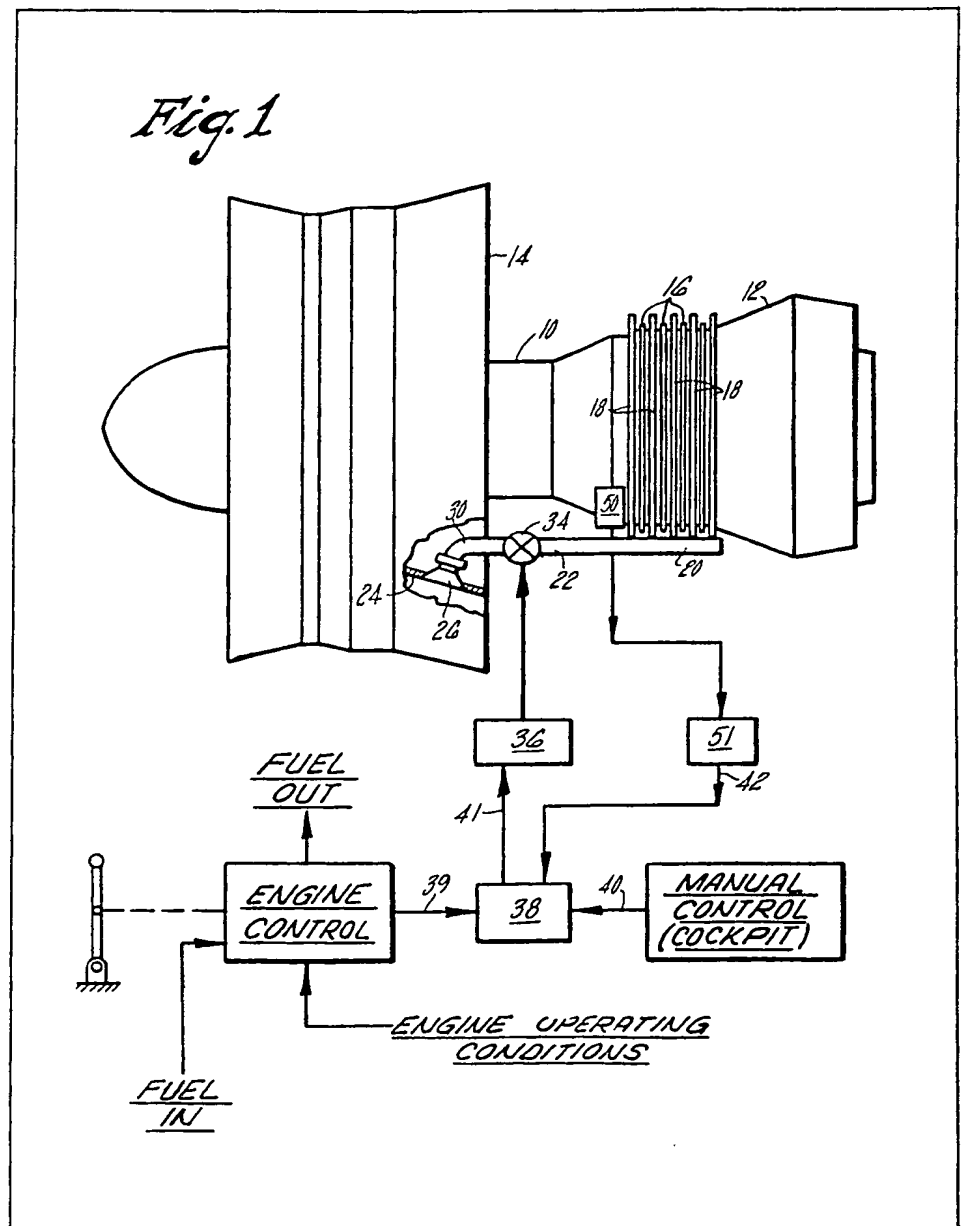
(12) UK Patent Application (19) GB (11) 2 104 966 A

- (21) Application No 8216720
(22) Date of filing 9 Jun 1982
(30) Priority data
(31) 277490
(32) 26 Jun 1981
(33) United States of America (US)
(43) Application published 16 Mar 1983
(51) INT CL³
F01D 11/08
(52) Domestic classification
F1G 6
(56) Documents cited
GBA 2063374
GBA 2024336
GBA 2057722
GB 1248198
GBA 2090333
(58) Field of search
F1G
F1T
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(54) Closed loop control for tip clearance of a gas turbine engine

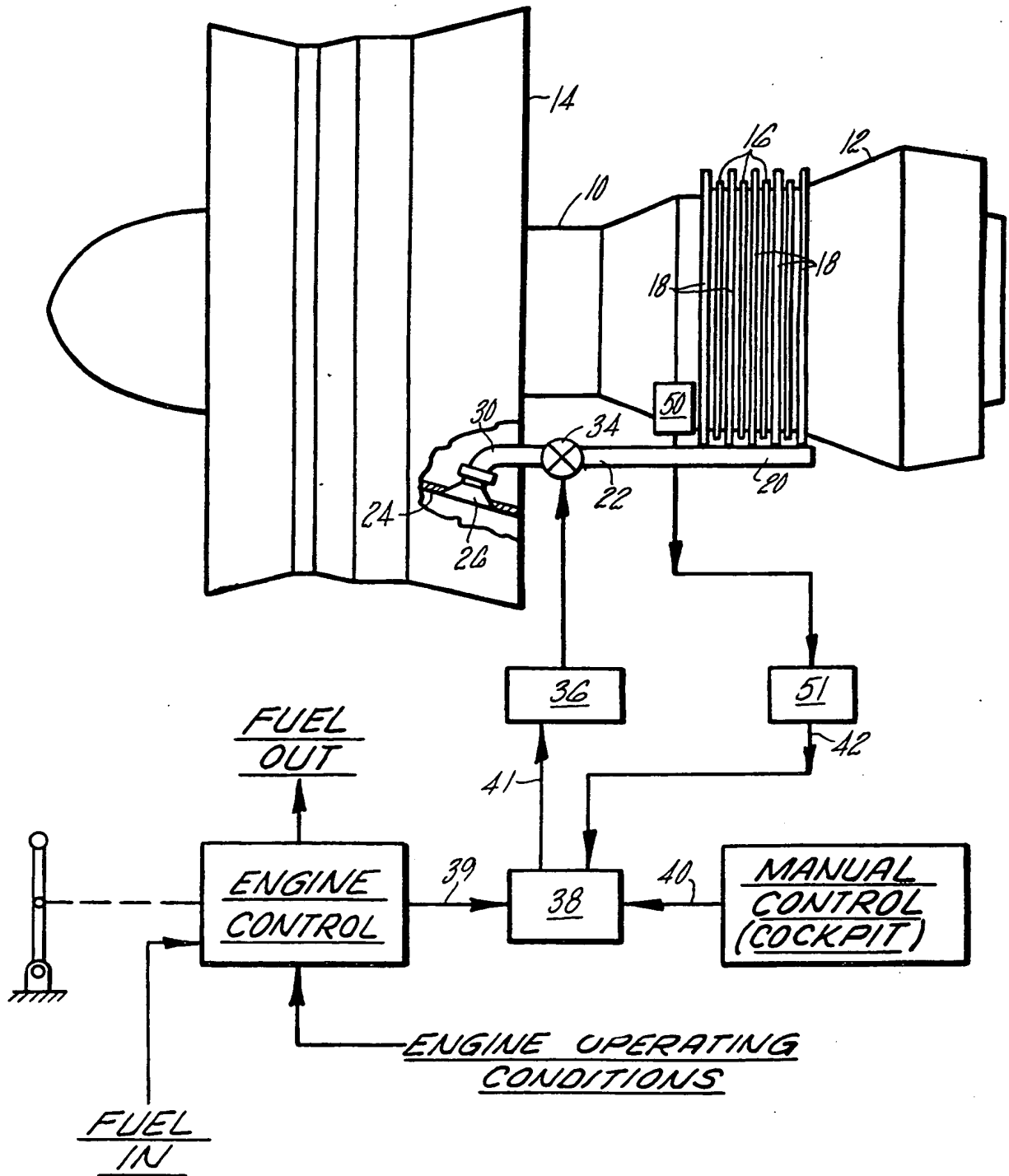
(57) The control functions by inputting sensed operating variables indicative of engine conditions and closing the

loop of said control as a function of the actual tip clearance sensed at 50 and fed back to be compared at 38 with the input signals. The error signal controls actuator 36 operating valve 34 to vary cooling air flowing to casing spray bars 18.



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Fig. 1



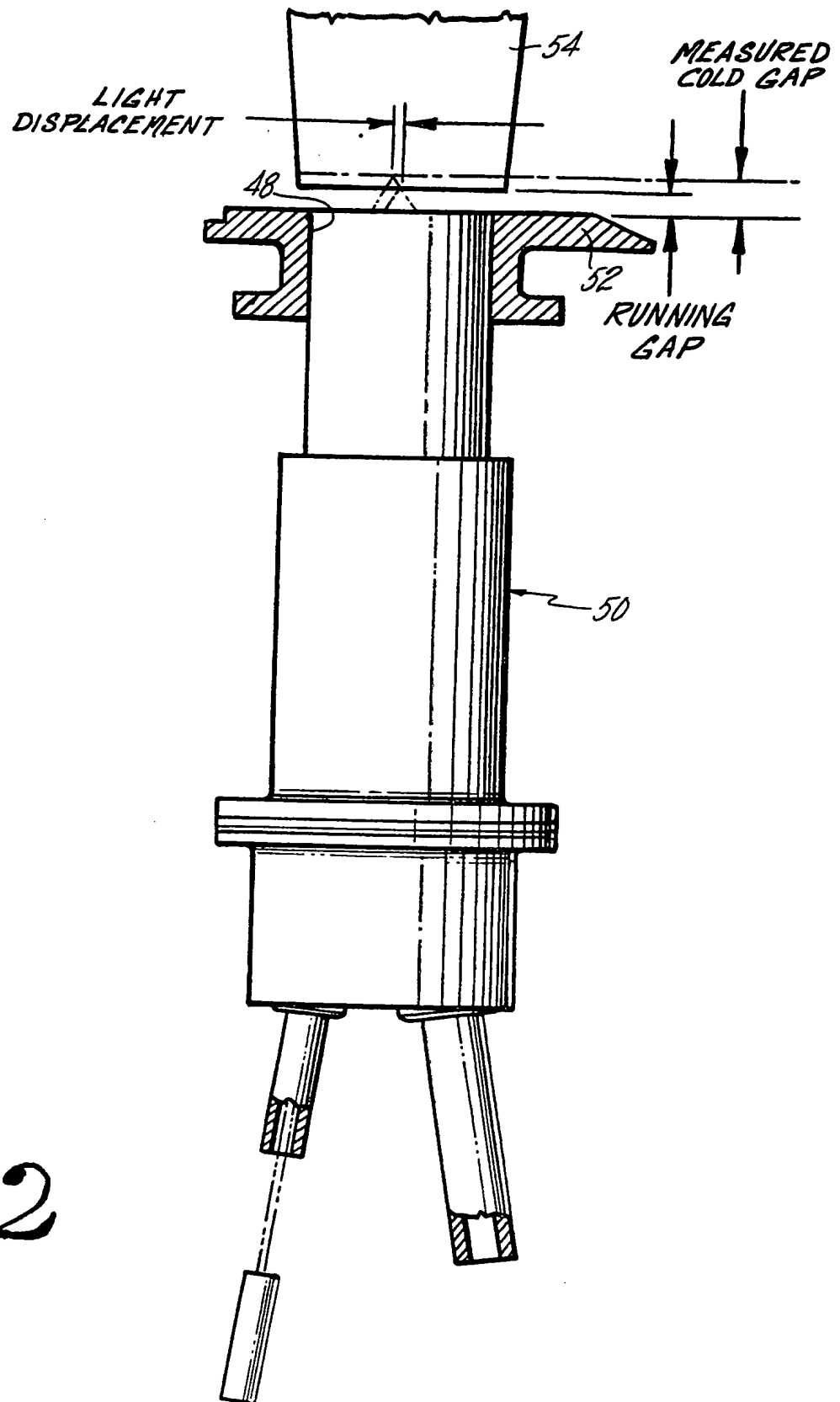


Fig 2

SPECIFICATION

Closed loop control for tip clearance of a gas turbine engine

Technical Field

5 This invention relates to active clearance controls for a gas turbine engine that controls the gap between the tips of the rotor blades and its cooperating seal and particularly to a closed loop system that closes the loop on the actual gap
10 dimensions.

Background Art

For reasons of good engine performance and improved fuel economy the industry has seen a concerted effort to minimize the gap between the rotating blades and their attendant seals. This
15 minimizes the air or engine working medium losses that are occasioned by bypassing the compressor or turbine blades rather than passing therethrough. Obviously the loss of energy can be
20 directly translated into engine operation penalties and hence, higher fuel consumption.

An example of a system for minimizing these losses is described in U.S. Patent No. 4,069,662 granted to I. H. Redinger, Jr., D. Sadowsky, P. S.
25 Stripinis and V. P. Laurello, on January 24, 1978 and assigned to United Technologies Corporation, the same assignee as this patent application which discloses and claims an active clearance control that externally impinges air on the engine
30 case and causes it to shrink to reduce the gap during certain operating modes. This patent discloses an open loop type of control system that monitors engine speed and/or barometric pressure and opens the cooling air valve upon reaching a
35 predetermined engine operating mode, say cruise condition.

The purpose of this invention is to improve on the system disclosed in Patent No. 4,069,662, supra by incorporating a closed loop control
40 system. This invention contemplates sensing the actual gap of the rotor blades, be it the compressor and/or turbine rotor, and change the gap until it matches a scheduled value, which may be a transient or a steady state condition. Thus,
45 the sensor could detect and transmit a clearance signal from the desired location on the engine, for example, first turbine blade tip to outer airseal, to the clearance controller. The controller would compare the measured clearance as determined
50 by the sensor with the desired clearance and drive a clearance control mechanism through an actuator until the actual clearance equals the desired clearance. The desired clearance is determined by the clearance controller in response
55 to signals input to it from the engine control and/or the cockpit.

Disclosure of Invention

An object of this invention is to provide for a gas turbine engine an improved system for
60 controlling the gap between the rotor blades and its peripheral seal.

A further feature of this invention is utilizing a

closed loop control that manifests a discrete schedule as a function of a signal that is produced
65 by the fuel control or within the cockpit of the aircraft such as operator positioning or aircraft maneuvers and closing the loop by positioning the seal as a function of the measured gap.

Other features and advantages will be apparent
70 from the specification and claims and from the accompanying drawings which illustrate an embodiment of the invention.

Brief Description of Drawings

Fig. 1 is a schematic view illustrating this
75 invention, and

Fig. 2 is a cutaway partial view partly in elevation and partly in section showing the gap sensing mechanism.

Best Mode for Carrying Out the Invention

80 While the invention is described showing the means for controlling the gap of the turbine and its seals by the air impingement on the engine case, it is to be understood that it is in the scope of this invention to employ other means. Additionally
85 while an optical gap sensor is shown in this preferred embodiment, other gap sensors may be employed without deviating from the scope of the invention.

As noted from Figs. 1 and 2, the invention is
90 illustrated as being utilized on a fan-jet engine as being exemplary and it is to be understood that other types of engines could equally employ the invention. The engine generally illustrated by reference numeral 10 comprises an engine core
95 casing 12 housing the compressor, burner and turbine sections and the bypass duct casing 14 housing the fan. For the sake of simplicity and convenience the details of the engine are omitted from this disclosure as they do not form part of the
100 invention. However, for further details of a suitable engine reference is hereby made to the JT-9D engine manufactured by Pratt & Whitney Aircraft Group, division of United Technologies Corporation, the assignee of this patent
105 application.

The casing may carry a plurality of axially spaced flanges 16 which extend from the casing and, in between flanges, are mounted air spray
110 bars 18 having a plurality of holes that flow air to impinge on the flanges. The impingement of air on the flanges serves to shrink or expand the case so as to move the outer air seal attached to the case relative to the tips of the turbine blades. The spray bars 18 are fed from a common manifold 20 that
115 connect to conduit 22. A portion of fan discharge air in duct 24 is scooped by scoop 26 and admitted into conduit 30 and feeds the manifold 20 with fan discharge air. While this invention in its preferred embodiment shows the use of fan air it is to be understood that any other medium for
120 contracting and expanding the case of movement of the seal relative to the tips of the rotor blades is contemplated within the scope of this invention. Mechanical contraction means could also be

employed without deviating from the scope of this invention.

The system as described above is essentially similar to the system described in U.S. Patent 4,069,662, *supra* and for further details reference should be made thereto and this patent is incorporated herein by reference.

In accordance with this invention a suitable modulating valve generally indicated by reference numeral 34 serves to modulate the air admitted to pipes 22 and hence manifold 20. A suitable actuator 36 serves to control the position of valve 34 which can move from full open to full closed and positions intermediate thereof.

In turn, actuator 36 is controlled by a suitable controller 38 which is of the closed loop type. The input signals fed through lines 39 or 40 is a desired clearance of the tips of the blades relative to its seal manifested by monitored signals that

are indicative of whenever a change of the gap will occur and the actual dimension of the gap fed to the controller via line 42. In other words, the controller will introduce an output error signal whenever a difference between the actual gap and the desired gap is indicated. Input signals are fed to the clearance controller either from a manual control in the cockpit via line 40 or from an alternate source like the fuel control via line 39.

Various operational modes are contemplated. In one preferred embodiment, the fuel control would be programmed to generate a desired clearance signal which was a function of engine operating condition. For example, the engine control has as inputs the steady state and transient operating

parameters of the engine such as rotor speed, pressure, pressure ratio and temperature. From these inputs in one preferred embodiment it would generate a desired clearance signal corresponding to selected "cruise" or "climb" operating conditions of the engine. In addition should any rapid changes occur, accelerations or decelerations, it would generate an appropriate desired clearance signal which would increase clearance during the engine transient period. This signal would be the normal operating mode of the system but could be overridden by a manually actuated signal from the cockpit which would allow, for example, clearances to be opened up during takeoffs, landings, or other special

maneuvers.

The clearance controller 38 would compare the desired signal received via lines 39 or 40 with the actual clearance signal which it received via line 42. It then generates a difference or error signal which it transmits to the clearance control valve actuator 36 via line 41. The actuator then drives the valve in a direction such as to reduce the error signal to zero.

The fuel control may take any form, as for example, the JFC—60 or JFC—68 manufactured by Hamilton Standard, division of United Technologies Corporation and an already computed available signal could be utilized to generate a desired or scheduled clearance control signal. In its preferred embodiment, an electronic

controller, as the one described in U.S. Patent No. 3,797,233 granted to W. L. Webb, T. R. Warwick, R. D. Hackney and R. L. Price on March 19, 1974 and also assigned to United Technologies

Corporation, is exemplary of a preferred control. This type of control lends itself to be programmed to schedule the gap for numerous maneuvers and conditions that the engine and aircraft would encounter.

The gap dimension sensor or proximity probe 50 and its associated transducer 51 generate the actual clearance signal which is transmitted to the clearance controller.

A suitable gap dimension sensor is shown in Fig. 2 where the laser proximity probe 50 is supported in an aperture 48 formed in outer air seal 52 mounted in proximity to and surrounding the partially shown turbine blade 54. Inasmuch as the invention is not particularly limited to the proximity probe *per se*, and other gap measuring devices can be equally employed, a description thereof is eliminated herefrom for the sake of simplicity and convenience. A suitable optical proximity probe is described in a 1974 paper ISA

ASI 74228 (133—140) entitled "Laser Proximity Probes for the Measurement of Turbine Blade Tip Running Clearance" by W. Drinkuth, W. G. Alwang and R. House which is incorporated herein by reference. Essentially a lens is utilized with a

prism to focus a laser beam onto the tips of the blade. The image, due to refraction of the laser beam through the prism is transmitted to the tip of the blade and reflected back through the prism and lens to the receiver fiber optic. By knowing the distance of the gap when in the undisturbed condition, the displacement of the image on the end of the receiver fiber optic is measured permitting the ascertainment of the change in the gap which is, in turn, transduced 51 to the actual gap signal transmitted to the controller.

It should be understood that the invention is not limited to the particular embodiments shown and described herein, but that various changes and modifications may be made without departing from the spirit and scope of this novel concept as defined by the following claims.

CLAIMS

1. A clearance controller for controlling the clearance between the tips of rotating blades of a gas turbine engine and the seal shrouding said rotating blades, means for positioning said seal relative to the tips of said blades to a predetermined distance, first means responsive to engine operating conditions for generating a schedule for selecting said predetermined distance over the engine operating envelope, second means responsive to said predetermined distance for generating a signal indicative of the actual clearance, actuator means responsive to the error between said first means and said second means for controlling said positioning means to position said seal to the predetermined distance to eliminate said error.

2. A clearance controller as in claim 1 including a fuel control for sensing given engine operating parameters and metering fuel to said engine as a function of a schedule commensurate with said engine operating parameters, said first means being responsive to a desired clearance signal manifested by said fuel control and manual means responsive to an operator for rendering said first means from producing an output signal for controlling said actuator means.

3. A clearance controller as in claim 2 wherein said means for producing said signal indicative of the actual clearance is an optical proximity probe that focuses a laser beam on the tips of said rotating blade which beam is reflected to a transducer for producing a signal indicative of the distance traveled from a given reference value.

4. In combination, a closed loop clearance control for a turbo-fan engine having a casing supporting a plurality of rotors having blades and seal means surrounding said blades attached to said casing, a fan duct surrounding the fan of said engine, means for impinging fan discharge air on the engine casing including a plurality of spray bars surrounding said casing, conduit means interconnecting said fan duct and said spray bars for leading fan discharge air to impinge on said

casing, valve means in said conduit means for regulating the flow of air therethrough, said closed loop clearance control including first means responsive to engine operating conditions for generating a desired clearance signal which is commensurate with the clearance intended for a given condition within the engine operating envelope, second means responsive to the actual clearance between the tips of said blades and its cooperating seal means for generating an actual clearance signal, means responsive to said first means and said second means for producing an error signal, and means responsive to said error signal for controlling said valve means so as to regulate the flow of air to cause said casing to move radially to change said clearance until said error is eliminated.

5. The combination of claim 4 including a fuel control responsive to engine operating parameters for metering fuel to said engine commensurate therewith and for manifesting a desired clearance signal for said rotating blade and its attendant seal means, and means responsive to an operator for rendering said desired clearance signal inoperative and controlling said valve means independently of said desired clearance signal manifested by said fuel control.